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TERRESTRIAL PRODUCTION VS. EXTRATERRESTRIAL DELIVERY OF PREBIOTIC ORGANICS TO THE EARLY EARTH

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Since early in this century, it has been speculated that Earth may have accreted much of the prebiotic organics necessary for the origins of life from impacts of carbonaceous asteroids or comets. This accretion would have been greatest during the period of heavy bombardment 4.5 to 3.8 Gyr ago. Over the last decade, this potential extraterrestrial source of organic molecules for the primitive Earth has taken on new importance, as an emerging consensus in planetary science has replaced previous models of a primordial reducing (CH_4/NH_3-rich) terrestrial atmosphere with that of a neutral (CO_2/N_2) one. Synthesis of key prebiotic molecules in CO_2 atmospheres has been shown experimentally to be much more difficult than in reducing ones, with production efficiencies dropping precipitously by many orders of magnitude as the ration H_2/CO_2 falls below unity. However, while these results are suggestive, there is certainly at present no requirement to invoke exogenous organics to account for the evolution of life on Earth. Many other speculative mechanisms for terrestrial prebiotic synthesis have been suggested. The goal of investigators at present must be to quantify as best as possible prebiotic organic production from the various proposed sources, so that their comparative importance may be weighed. A kind of "balance sheet" for organic production from different sources in various putative early terrestrial atmospheres may then be constructed.

A comprehensive treatment of comet/asteroid interaction with the atmosphere, ensuring surface impact, and resulting organic pyrolysis is required to determine whether more than a negligible fraction of the organics in incident comets and asteroids actually survived collision with Earth. Results of such an investigation, using a smoothed particle hydrodynamic simulation of cometary and asteroidal impacts into both oceans and rock, demonstrate that organics will not survive impacts at velocities $\gtrsim 10$ km s^{-1}, and that even comets and asteroids as small as 100m in radius cannot be aerobraked to below this velocity in 1 bar atmospheres. However, for plausible dense (10 bar CO_2) early atmospheres, there will be sufficient aerobraking during atmospheric passage for some organics to survive the ensuing impact. Combining these results with analytical fits to the lunar impact record shows that 4.5 Gyr ago Earth was accreting at least $\sim 10^6$ kg yr^{-1} of intact cometary organics, a flux which thereafter declined with a ~100 Myr half-life. The extent to which this influx was augmented by asteroid impacts, as well as the effect of more careful modelling of a variety of conservative approximations, is currently being quantified. These results may be placed in context by comparison with *in situ* organic production from a variety of terrestrial energy sources, as well as organic delivery by interplanetary dust. Which source dominated the early terrestrial prebiotic inventory is found to depend on the nature of the early terrestrial atmosphere. However, there is an intriguing symmetry: It is exactly those dense CO_2 atmospheres where *in situ* atmospheric production of organic molecules should be the most difficult, in which intact cometary organics would be delivered in large amounts.